1 Protecting the Integrity of National Park Resources and Values

National parks represent a contract between Americans today and generations of Americans yet to come. As a nation, we have promised to leave these extraordinary places of discovery and power in a condition that is unimpaired so that they will continue to serve the needs of society to connect to authentic places for their educational, recreational, and restorative values. As citizens we look to the National Park Service to ensure that this ongoing commitment is undeterred and undiminished.

"The days of the past, when we could escape our workaday world for the pristine environment of our national parks, are being rapidly replaced by a world where preserving the national parks will depend more on what happens outside the parks than within them." **—Bob R. O'Brien**

Yet national parks today are evolving under influences that are not only the result of local park resource interactions but also consequences of human activities. Environmental factors both within and outside national park boundaries affect park values such as solitude, ecological wholeness, clean air and water, biodiversity, endemic species, healthy forests and fisheries, and educational and recreational opportunities. As the articles in this chapter and throughout this edition of *Natural Resource Year in Review* suggest, management can succeed in protecting the integrity of many park resources and values, though not in all cases or at all scales. For example, infestations of nonnative species are so vast and the spread of forest diseases often so rapid that treatments require prioritization to address the greatest needs and to make the best use of available staff and funds. Fortunately, one of the most precious values of the national parks is their ability to teach us about ourselves and how we relate to the natural world. This important role may prove invaluable in sustaining us as a species as we strive to uphold our national parks.

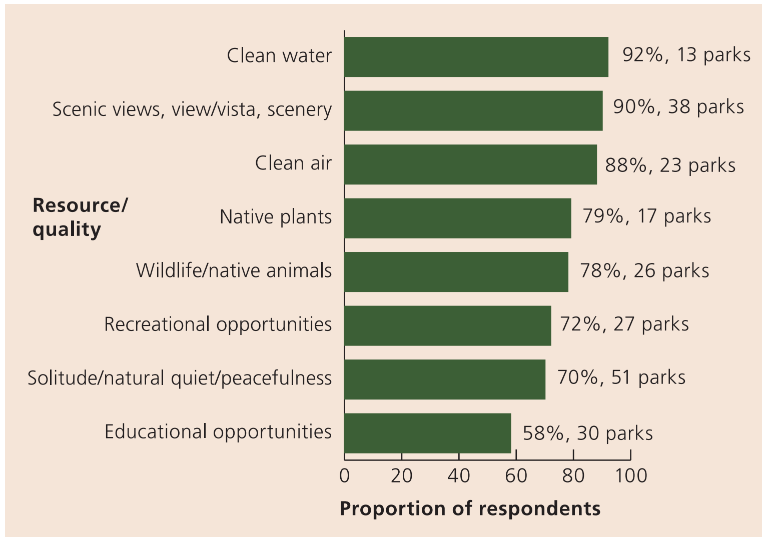
Visitor feedback offers invaluable insight for resource managers

By Lena Le, Margaret Littlejohn, and Steven Hollenhorst

IN 2006, USING THE MOST RECENT DATA, PARK managers across the country had the opportunity to "hear" visitor opinions on the importance of protecting park resources and values. Results of visitor studies conducted by the Visitor Services Project (VSP) show that visitors rated clean water, scenic views, and clean air as the most important resources in the national parks. Visitor groups selected by random sample were given a mail-back questionnaire as they entered a park and were asked to complete it after their visit. They rated the importance of protecting park resources, such as native plants and animals, historical buildings, and archaeological sites, in addition to those already mentioned. They also rated the importance of resources that enable them to enjoy their visit to national parks, including solitude/quietness, night sky, scenic views, recreational opportunities, and educational opportunities.

The Visitor Services Project began in 1982 when the National Park Service (NPS), recognizing the need to learn more about visitors and their opinions, asked the Park Studies Unit at the University of Idaho to develop a new approach to visitor studies. This ongoing feedback provides NPS managers with critical information. It helps them enhance visitor services, preserve the integrity of park resources and values, and accomplish their overall park management goals. From 1990 to 2005, the Visitor Services Project conducted 148 studies in national parks (with some parks having repeat studies), and averaged a 75% response rate. Each survey questionnaire was customized to provide visitor feedback on issues important to each park's managers.

Among the 148 studies, researchers selected 56 that contained the same question asking visitors to rate the importance of park resources. Since four parks had repeat studies, these 56 studies present visitor opinions from 52 parks. Visitors rated the importance of protecting park resources on a 5-point equal-interval scale, with 5 being "extremely important" and 1 being "not important." Although the question and scale remained the same, the items rated varied according to the presence of particular resources at each park. The comparable items included clean air, clean water, scenic views, native plants, native wildlife, recreational opportunities, educational opportunities, and solitude. Although 52 is a small number compared with the total of 391 units, these parks represent the variety of the National Park System in terms of unit size, type, available resources, and location. In addition, by aggregating opinions of more than 23,000 respondents, the data provide good representation of public opinions about the importance of protecting park resources.

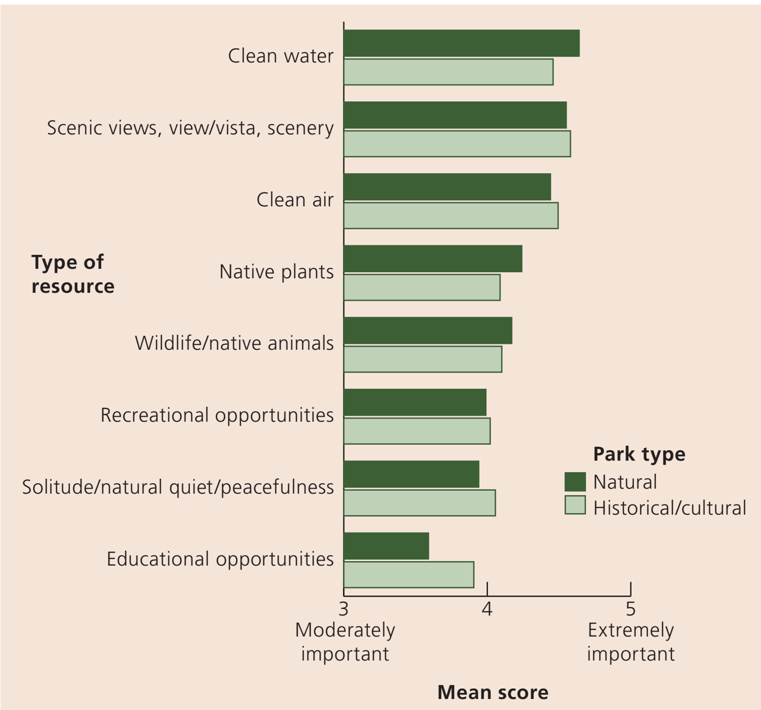


Combined percentages of visitors who rated various park resources as "extremely important" or "very important."

Overall, a sizable majority of visitors rated the protection of specific park resources as "extremely important" or "very important" (graph, above). In particular, 92% of respondents rated "clean water" and 88% rated "clean air" as "extremely important" and "very important," respectively. This shows that visitors are aware of, and support, the national park mission to protect these park resources.

For this analysis, parks were placed in two general categories—natural and cultural/historical—based on each park's primary resource. Regardless of park type, visitors demonstrated a similar pattern in the order of importance for resources selected. Clean air and clean water were of utmost importance. Scenic views and vistas are related to air quality in that visibility allows visitors to enjoy park scenery and preserved landscapes. This finding is evidence that visitors perceive recreational and educational opportunities as less important than protecting park values related to air quality, watershed, and native plants and animals (graph, next page).

Visitors rated clean water, scenic views, and clean air as the most important resources in the national parks.



Comparisons of mean score for importance ratings of park resources.

However, some differences by park type were evident. Natural resources (plants and animals) were perceived as more important in a natural setting than in a cultural or historical park. Cultural and historical parks were perceived as more important in providing educational opportunities to visitors than were natural resource–based parks. Nevertheless, the differences were not large in that many parks have both natural and cultural or historical resources.

Clearly, visitors who participated in these surveys understood the importance of global environmental resources such as clean air and clean water and, to a certain extent, native plants and animals. However, in contrast they perceived educational opportunities as relatively less important than the other resources listed in the graphs, especially in natural resource–based parks. Managers must consider many aspects of these complex issues, such as the costs and benefits of particular policy or management decisions relating to these resources. Nonetheless, these findings serve as general social indicators for managers of cultural and natural resources as well as for interpreters to contemplate as they strive to increase visitor awareness of critical park resources and issues. ■

lenale@uidaho.edu
Assistant Director, Visitor Services Project, University of Idaho, Moscow, Idaho

littlej@uidaho.edu
Director, Visitor Services Project, University of Idaho, Moscow

stevenh@uidaho.edu
Director, Park Studies Unit, and Department Head of Conservation Social Sciences in the College of Natural Resources, University of Idaho, Moscow

Commons without tragedy: Measuring and managing carrying capacity in the national parks

By Robert E. Manning

IN 1968, GARRETT HARDIN PUBLISHED A HAUNTING paper—"The Tragedy of the Commons"—in the prestigious journal *Science*. Now a foundational piece of environmental literature, the article portrayed national parks as an example of common property resources and described the tragic consequences of overuse. Since that time, annual visitation to the National Park System has nearly doubled and now approaches 300 million recreational visits per year. How many visits can the national parks ultimately accommodate without unacceptable impacts to park resources and to the quality of the visitor experience?

In the context of parks and related areas, this issue is often called carrying capacity. In recent years, the National Park Service (NPS), in consultation with academic and government scientists, has developed and applied a framework for addressing carrying capacity called Visitor Experience and Resource Protection (VERP). VERP starts with the development of management objectives (or "desired conditions") for park resources and for the quality of the visitor experience. These management objectives must ultimately be expressed in quantitative "indicators" and "standards." Indicators are measurable, manageable variables that are proxies for management objectives, and standards define the minimum acceptable condition of indicators. Under this procedural model, indicators are monitored and, when necessary, management actions are taken to ensure that standards are maintained. VERP has been applied in a number of diverse units of the National Park System, and the underlying conceptual framework of indicators and standards has now been adopted into the NPS general management planning process. Applications of VERP have been supported by a program of natural and social science research.

In 2006, studies at Muir Woods National Monument (California) provided an illustration of this research and planning approach. An initial survey of visitors to Muir Woods found that many respondents reported that the number of people encountered on park trails and the noise they made were important in defining the quality of the visitor experience. Thus these two variables are potentially important indicators of both resource and social conditions for the park. But what are appropriate standards for these variables? Subsequent phases of study addressed this question.

First, a series of computer-generated photographs of trail use was prepared and incorporated into a visitor survey. These six photographs showed a range of visitor use levels along a 75-foot (23-meter) section of trail (or typical "viewscape"). Survey respondents were asked to rate the acceptability of each photograph based on the number of hikers shown. Average acceptability ratings are shown in the graph. These data help provide an empirical basis for formulating a crowding-related standard. For example, average response scale values fall out of the acceptable range and into the unacceptable range at approximately 16 people per viewscape. Respondents were also asked to indicate which photograph they preferred to see, which photograph was so crowded that they would not return to Muir Woods, and which photograph showed the maximum level of use the National Park Service should allow. A computer simulation model of visitor use of the trail system was also developed to estimate the maximum daily use of the park without violating crowding-related standards on the trails.

In other studies, responses can vary depending on which questions are asked. For example, visitors' response to the maximum number of visitors the National Park Service should allow can be much higher than the number that is acceptable to the visitors themselves. This suggests that visitors understand that trade-offs exist between access to public areas and

These study photographs illustrate a range of trail use levels (i.e., persons-per-viewscape or PPV) at Muir Woods National Monument.

An initial survey of visitors to Muir Woods found that many respondents reported that the number of people encountered on park trails and the noise they made were important in defining the quality of the visitor experience.

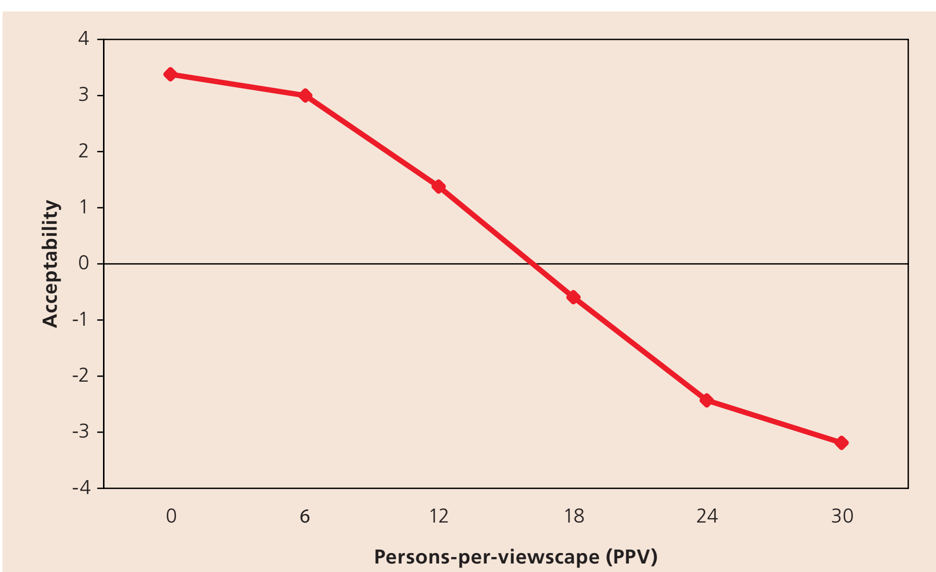
protection of individual experiences and that they are willing to accept some level of use below their "acceptable" range in order to maintain public access.

Second, in an analogous way, a series of five 30-second audio tracks was developed that portrayed a range of visitor-caused noise in the park. These audio tracks were prepared from sound recordings taken in the park, and the audio tracks were incorporated into a visitor survey. Respondents listened to and rated the acceptability of each audio track. Findings suggest that most respondents feel that it is unacceptable to hear visitor-caused noise more than half the time they are in the park. These findings help to provide an empirical basis for formulating noise-related standards. Ongoing research is exploring the effectiveness of management efforts to reduce visitor-caused noise in the park, and preliminary findings are encouraging. (See the following article on the NPS Natural Sounds Program for more information on this and related research.)

The current work at Muir Woods is an extension of a program of research, planning, and management that has been conducted in many diverse units of the National Park System. Information has been developed on a range of indicators and standards, including trail, campsite, and river encounters; people per viewscape along trails; people at one time at attraction sites; waiting time for services and facilities; resource impacts on trails and at campsites; development of unofficial social trails; automobile traffic; type and level of facility development; litter and graffiti; size of hiking and tour groups; availability of parking; and visitor-caused noise.

This work has recently been summarized in a new book titled *Parks and Carrying Capacity: Commons Without Tragedy*, published by Island Press. This work has been conducted by a number of planners, managers, and researchers inside and outside the National Park Service. The book suggests that we now have the conceptual foundations, an associated planning and management framework, a growing set of supporting research approaches, an array of management practices, and a number of encouraging case studies that allow us to engage carrying capacity more deliberately. In other words, we can have commons, including national parks, *without* tragedy. Of course, applying these planning, management, and research approaches will be challenging and sometimes even contentious. Failure to do so, however, would likely result in issues that are even more difficult or impossible to resolve in the future. ■

Robert.Manning@uvm.edu
Professor, Rubenstein School of Environmental and Natural Resources, and Director of the Park Studies Laboratory, University of Vermont, Burlington



Social norm curve for trail use levels at Muir Woods National Monument.

Advancing air tour management plans and protecting soundscapes in national parks

By Karen Trevino

SOUNDS HAVE A POWERFUL EFFECT ON HUMAN emotions, attitudes, and memories and enhance the ability to process, comprehend, and understand the world. Hearing and being heard are also important for wildlife because many animals depend on acoustic communication for finding food, avoiding predators, establishing territory, courting and mating, and nurturing young. For the National Park System, however, a healthy acoustic environment is not limited to the sounds of nature; cultural and historical sounds are also significant components. The sound of a cannon shot echoing across a Civil War battlefield and the hypnotic drumbeat of a sacred tribal dance bring the past to the present and elicit a sense of relation to our ancestors. The sounds of people enjoying the parks through a variety of recreational activities are also a common element of the soundscape in national parks.

Officially established in 2000, the National Park Service Natural Sounds Program provides park managers with

As part of the air tour management planning process for Mount Rushmore National Memorial (South Dakota), the Natural Sounds Program and the John A. Volpe Center installed monitoring equipment to collect acoustic data. The draft environmental assessment, part of the air tour management plan for the memorial, is nearly completed. However, the FAA and National Park Service need to resolve differences in methodologies for assessing impacts, including analyses of visitor security and the potential for air tour noise to interfere with various types of communications (e.g., visitor conversations, public speeches, interpretive programs, and safety announcements).

Development of the air tour management plan for Kalaupapa National Historical Park (Hawaii) was indefinitely suspended after commercial air tour operators withdrew their applications for interim operating authority. The FAA confirmed that air tour operators did not intend to conduct air tours over the park, and all commercial operations ceased by January 2007. It is unlikely an air tour operator could apply for operating authority over Kalaupapa in the future and the planning process would start again.

technical assistance and national policy development and guidance for a consistent approach to managing acoustic environments. In 2006 the Natural Sounds Program assisted 39 parks with data collection and analysis, monitoring, and planning. Developing soundscape goals, objectives, and standards and identifying appropriate measures for mitigating noise impacts are part of the planning process.

Integral to the Natural Sounds Program is working with the Federal Aviation Administration (FAA) to provide the necessary tools for implementing the National Parks Air Tour Management Act of 2000. The National Park Service and the FAA jointly develop air tour management plans for all parks with commercial air tours. Currently 106 National Park System units have commercial air tours; other areas will need plans whenever an air tour operator requests to fly within 0.5 mile (0.8 km) of a park's boundaries. Air tour management plans determine the most effective means for safety and environmental protection with the least impact to the air tour industry and park resources. Plans determine if, when, or where commercial air tours will occur over National Park System lands, specifying flight routes, direction, minimum altitudes, time of day, and number of flights. Planning involves many steps: acquiring acoustic data, which must be completed a year before beginning work on an air tour management plan in order to capture seasonal differences; characterizing the ambient acoustic baseline; analyzing impacts to park resources and visitor use; overseeing contractors; providing scientific expertise for soundscape management; administering the NPS obligation of funding 40% of all air tour management plans; implementing quiet technologies; and executing the recommendations of the National Parks Overflights Advisory Group.

To date, park and program staffs have collected acoustic data in 20 of the 106 parks with air tours. Voluntary agreements regarding overflights exist in 5 parks. Kickoff meetings among FAA, Natural Sounds Program, and park staffs have taken place in 16 parks, and development of air tour management plans is under way in 5 parks (i.e., Hawaii Volcanoes, Haleakala, Badlands, and Grand Canyon national parks, and Mount Rushmore National Memorial). In addition the National Park Service worked closely with the FAA and congressional committees to amend the 2000 act to give park superintendents more flexibility in the development of air tour management plans.

Supporting acoustic research and technology development is another component of air tour management planning because federal mandates direct the National Park Service to use the best available science and technology in making management decisions. The National Park Service uses noise metrics and analysis protocols that assess, mitigate, and prevent impacts on park resources and visitor enjoyment. The Natural Sounds Program is in the process of improving existing metrics and in some cases developing new metrics more aligned with NPS management objectives. Program staff is pursuing technical peer review from the Federal Interagency Committee on Aircraft Noise and publishing the improved and new metrics in relevant acoustic journals.

The Natural Sounds Program continues to develop reliable, innovative, cost-effective technologies for collecting acoustic data that can be deployed, monitored, and maintained with minimal staff time and resources. Program staff developed user-friendly monitoring software so park staff and volunteers could help maintain equipment without extensive training. The Natural Sounds Program is developing automatic signal processing that will increase the efficiency and speed of analyzing data. The data obtained from the monitors now run through several scripts to produce a spectrogram, providing a quick visual analysis of a day's worth of acoustic data. To further reduce both the cost of analysis and the time required to provide park managers with a final report, much of the data visualization is automated. Furthermore, because of a more efficient data logger, third-generation acoustic monitoring stations now in use consume only about one-fifth of the power of previous stations. Investigators can also monitor previously inaccessible areas (e.g., dense forest and areas with heavy rainfall) because solar panels are no longer required.

Air tour management plans determine the most effective means for safety and environmental protection with the least impact to the air tour industry and park resources.

Given the inextricable link between natural and culturally appropriate sounds and overall park experience, the NPS Natural Sounds Program is working closely with several universities to study the relationship between visitors and soundscapes. In Muir Woods National Monument (see previous article) investigators from Colorado State University and the University of Vermont conducted surveys to determine acceptable levels of human-caused sound. Colorado State University also carried out listening exercises in Yosemite and Grand Teton national parks to understand visitor perceptions about sound sources in parks. Virginia Polytechnic Institute will be conducting similar surveys and listening exercises in Haleakala and Hawaii Volcanoes national parks and has already begun research on the effects of noise generated by hikers in Great Smoky Mountains National Park. The latter study includes the development of a computer model that simulates both visitor traffic and the noise it generates. Additionally, Southern Utah University conducted surveys in Bryce Canyon National Park to examine the relationship between the acoustic experience and the psychological responses of visitors. More research is expected for the 2007–2008 season. ■

karen_trevino@nps.gov
Program Manager, NPS Natural Sounds Program, Fort Collins, Colorado

Springs and seeps: Inventories provide data on at-risk wetland resources in Mojave Desert Network parks

By Debra Hughson, Terry Fisk, and Don Sada

IN THE ARID EXPANSES OF THE MOJAVE DESERT (California and Nevada), various scattered seeps, springs, and small riparian areas support endemic aquatic biota, rare plants, and wildlife. They also provide an invaluable source of water for human use and are, in turn, greatly impacted by such use. In 2006, through a cooperative agreement, the Desert Research Institute, the Great Basin Institute, and the National Park Service began exhaustive inventories of these "desert water holes" to evaluate their overall health using a protocol developed for the Mojave Network Inventory and Monitoring (I&M) Program (Sada and Pohlmann 2006). Focusing on groundwater and surface water dynamics, in part because of the vital connection between spring discharge and groundwater levels, which are susceptible to impacts from groundwater pumping, researchers collected basic data on springs, including brook length, spring type, approximate discharge, temperature, and substrate composition.

Drawing upon combined resources and technical staff, national parks across the nation have formed networks to better monitor and inventory ecosystems and identify critical indicators of ecological health, called vital signs. The Mojave Network includes Great Basin National Park (Nevada), Death Valley National Park (California and Nevada), Lake Mead National Recreation Area (Nevada and Arizona), Grand Canyon–Parashant National Monument (Arizona), Mojave National Preserve (California), Joshua Tree National Park (California), and Manzanar National Historic Site (California). For parks in the Mojave Network, water quantity and quality are vital signs because their condition is sensitive to increased regional water use and development outside the parks. For this project, staff surveyed 630 springs in Death Valley National Park, 80 in Lake Mead Recreation Area, 228 in Grand Canyon–Parashant National Monument, and 156 in Joshua Tree National Park. Great Basin National Park had already completed its inventory of 210 springs, Mojave National Preserve is completing its inventory of 183 springs, and Manzanar National Historic Site has no springs.

Based on the extent of the aquifers that supply their flow, springs in the Mojave Network are characterized as local or regional. Local springs are fed by recharge from within a local watershed, have a water temperature typically reflecting the annual mean temperature of that watershed, and are found at higher elevations than regional springs. These springs may be intermittent and, as a general rule, are not persistent over long periods of geologic time. By contrast, regional springs discharge from extensive aquifers that cover tens of thousands of square miles and can underlie many local watersheds. These springs are typically warm because of deep circulation. They can also discharge appreciable volumes of water and, most importantly, are persistent through geologic time—tens of thousands to perhaps millions of years. Because of this persistence, they are characterized by rich species diversity and high levels of endemism.

Death Valley alone has 521 springs, ranging from marshlands along the Amargosa River to numerous intermittent mountain-front seeps. The Saline Valley and Panamint Valley portions of Death Valley National Park add 57 and 51 more springs to the park's database, respectively. Most springs in Death Valley lie below 4,200 feet (1,280 m) in elevation and discharge less than 26 gallons/minute (100 liters/minute). Spring brook lengths are typically less than 656 feet (200 m). However, some springs discharge several hundred or more gallons per minute and have spring brook lengths

Saratoga Springs lies in southern Death Valley National Park near the course of the intermittently flowing Amargosa River. Five rare invertebrate species and Saratoga Springs pupfish (*Cyprinodon nevadensis nevadensis*) live here. Water resources are invaluable to Mojave Network parks, and such baseline information on water quality and quantity enables managers and staff to better protect these resources in the face of groundwater development.

Great Basin Institute staff inspects a spring in an abandoned shaft near the Keane Wonder mine in Death Valley National Park. Some riparian vegetation can be seen beyond the signpost.

Rogers Spring at Lake Mead National Recreation Area, one of two refugia for the leopard frog.

National Park Service and USGS scientists collect water quality data at a vernal pool in the Grapevine Springs area of Death Valley National Park.

The future of Mojave Network park springs and their rare, endemic biota is uncertain in the face of climate change and human enterprise. Inventories of springs and aquatic biota in the desert parks provide knowledge to inform the public of these at-risk resources.

up to 3 miles (5 km) long. Because of impacts from natural events and human activities, about 70% of the area's springs are in a moderately to highly disturbed state, which is critical in that a significant fraction of these water bodies supports a unique assemblage of desert aquatic biota, including several species of fish. The most famous, the Devils Hole pupfish, is now down to a double-digit population. Other aquatic macroinvertebrates (mollusks, aquatic insects, and crustaceans) and rare plant communities are found only in these springs. A number of the springs in Lake Mead National Recreation Area that support significant riparian resources are fed by the same regional carbonate aquifer that is exposed in Devils Hole. One of two distinct populations of the endemic leopard frog (*Rana onca*) occurs only in Blue Point Spring and Rogers Spring. Mojave Network springs are also important as water sources for terrestrial animals and support riparian systems that are important nesting sites for birds.

Most springs in the West have been altered by livestock, feral horse, and burro trampling, as well as by surface diversions (e.g., spring boxes, pipes, troughs, and dredging). Crayfish, nonnative fish, and mollusks, introduced for recreation, mosquito control, and by accident, also impact the springs. In Grand Canyon–Parashant National Monument, nearly all springs have been highly modified by humans, primarily for use by livestock. More than 100 springs in Mojave National Preserve were once diverted for livestock watering. More recently, however, the regional carbonate aquifer that supplies springs in Death Valley and Lake Mead has been a focus of concern. Plans for continued urban growth in Clark County, Nevada, have led the Southern Nevada Water Authority to seek additional water supplies within the state but outside of Clark County to supplement the meager Colorado River allotment given to them under the early 20th-century Colorado River agreements. Spring Valley, situated on the west side of Great Basin National Park in east-central Nevada, and Three Lakes and Tikapoo valleys, situated northwest of Las Vegas, are sites of the latest groundwater rights granted to the city. These and other pending applications in eastern and southern Nevada may someday impact springs in Great Basin National Park, Lake Mead National Recreation Area, and Death Valley National Park. Groundwater extracted from pumping wells must eventually be derived from intercepted natural discharge, with the relevant questions being how long until the effects are noticeable and what effects society is willing to accept. Inevitably, water drawn from wells will lower groundwater levels, which will adversely impact areas of natural discharge, including, perhaps, springs inside national parks.

Drought years also affect spring discharge. In the Mojave Desert and Great Basin national parks, almost all recharge to aquifers occurs as precipitation above 6,000 feet (1,830 m). Longer periods of drought in the Southwest, occurring as a result of climate change, will likely decrease the overall volume of recharge. An investigation into the susceptibility of three springs in the Mojave Network to climate change and groundwater development is currently under way through a USGS-NPS Water Quality Partnership. Specifically, the study is looking at water quality–discharge relationships as they affect amphibian populations.

The future of Mojave Network park springs and their rare, endemic biota is uncertain in the face of climate change and human enterprise. Inventories of springs and aquatic biota in the desert parks provide knowledge to inform the public of these at-risk resources. The timing and magnitude of changes to aquatic resources remain unknown. Monitoring at key locations will improve our understanding of Mojave spring ecosystems and our ability to manage the risks. ■

Reference

Sada, D. W., and K. F. Pohlmann. 2006. U.S. National Park Service Mojave Inventory and Monitoring Network Spring Survey Protocols: Level I and Level II. Desert Research Institute, Reno and Las Vegas, Nevada.

debra_hughson@nps.gov
Science Advisor, Mojave National Preserve, California

terry_fisk@nps.gov
Hydrologist, Death Valley National Park, California

Don Sada
Associate Research Professor, Desert Research Institute, Reno and Las Vegas, Nevada

Water quality monitoring assessment of four park units on the Colorado Plateau

By Charlie Schelz

IN THE HIGH DESERT OF THE COLORADO PLATEAU, water means life. Surface water in seeps and springs, streams and potholes, and the Colorado and Green rivers usually proves adequate to support plants and animals adapted to this arid environment, but a variety of circumstances can upset the delicate balance of water quantity and quality. Threats include climate change, changes due to drought or high-intensity storms, vehicles traveling within stream channels, groundwater pumping and contamination from domestic and industrial wells, and upstream disturbances that might include septic system discharges or runoff from agriculture, roads, off-road vehicles, energy development, mining, new housing, or livestock grazing. Tracking onetime events and long-term trends, either human-induced or natural, provides information about this critical resource that can make the difference between life and death in the desert.

Canyonlands National Park, Arches National Park, Hovenweep National Monument, and Natural Bridges National Monument, known collectively as the Southeastern Utah Group, monitor water quality and quantity in each of those parks. Monitoring began in 1983, conducted by Division of Resource Management staff in cooperation with park river rangers, and is now supported by the National Park Service (NPS) Inventory and Monitoring Program, the NPS Water Rights Division, the U.S. Geological Survey, and the State of Utah Division of Water Quality. Samples are

Seeps, springs, and rivers are the lifeblood of the desert, bringing critical moisture to a parched landscape. A program of water quality and quantity monitoring is designed to track conditions of this important resource in four national parks in southeastern Utah.

A four-wheel-drive route in Peekaboo Spring is one of a number of water quality monitoring sites in the Needles District of Canyonlands National Park.

monitored for a wide range of chemical parameters, aquatic macroinvertebrates, and fecal indicator bacteria. Water quantity or flow is also measured. Results of chemical testing are made available via the Internet in the national STORET system managed by the United States Environmental Protection Agency (www.epa.gov/storet/dbtop). A detailed analysis of trends from 1994 to 2004 is available in reports for each park.

Water quality in the four park units usually ranges from good to excellent, though temporary surges in some chemicals or conditions have occurred as a result of extreme weather. Elevated numbers most commonly reflect total phosphorus and manganese in seeps and springs that exceeded primary drinking water standards. Dissolved solids exceeded secondary drinking water standards at many of the sites monitored. Total suspended solids and turbidity exceeded standards numerous times at all sites on the Green and Colorado rivers. Excess aluminum, sulfate, and selenium are also problems at river sites.

In Salt Creek in Canyonlands National Park, elevated levels of fecal indicator bacteria, turbidity, total suspended solids, and water temperature are apparently the result of vehicles traveling in the stream channel. Most of the four-wheel-drive route in Salt Creek was closed in 1998 as a result of a lawsuit brought by a consortium of environmental groups against the National Park Service. Unpublished program data clearly show an impact on water quality at Peekaboo Spring in the section that remains open. In addition to the impacts noted above, aquatic macroinvertebrate species diversity appears to be about 25% lower than that in similar sites without vehicle access.

In the program's early stages, observations and crude measuring techniques provided estimates of water quantity. Over the years, a better understanding of the extreme ecological importance of the amount of available water led the NPS Water Rights Division and hydrologists from the U.S. Geological Survey and the State of Utah to assist the parks in developing more accurate methods of measurement. In Colorado Plateau parks, seeps and springs represent some of the most ecologically significant and endangered habitats, even though they constitute less than 1% of the land surface. Accurate measurements of water quantity and ensuring continuation of water flow rights are necessary to protect these and other critical natural resources on the Colorado Plateau.

Tracking onetime events and long-term trends, either human-induced or natural, provides information about this critical resource that can make the difference between life and death in the desert.

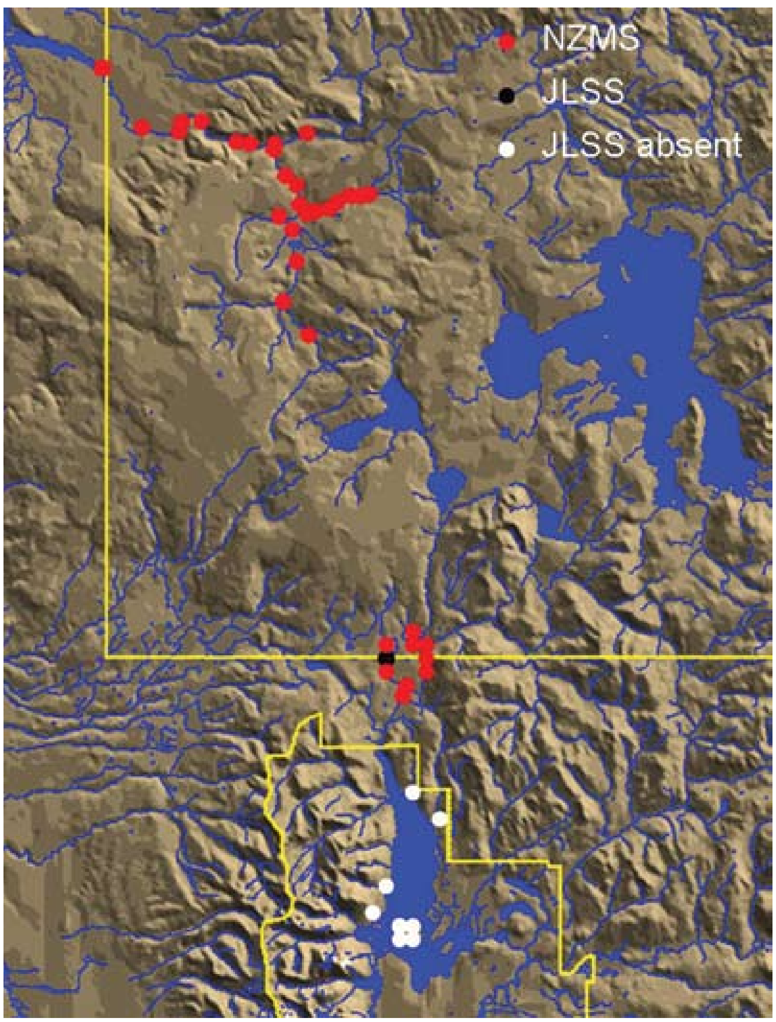
The lack of available funding for measuring water flow has limited this extremely important monitoring to a few springs and seeps in Arches National Park and in Hovenweep National Monument. Much more monitoring should be done in both parks. Monitoring baseline flows for these systems helps to anticipate potential effects of flow alterations in the future. Since 2000, a slight downward trend in the springs and seeps along the western boundary of Arches National Park coincides with recent commercial and domestic development, stimulating concern that domestic and industrial water wells may draw down the groundwater aquifer or that sewage from septic systems may contaminate surface water. This downward trend may be a natural result of the recent drought the area has experienced, or it may be influenced by human activities. The National Park Service has identified adjacent land development as a serious threat to water quantity and quality; only continued monitoring would answer these questions and provide guidance for the future. ■

charlie_schelz@nps.gov
Ecologist, Southeastern Utah Group, Moab

Invasive snail poses threat to endemic species in Greater Yellowstone

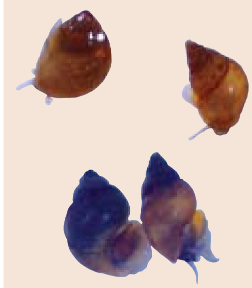
By Leslie Riley, Mark Dybdahl, Susan O'Ney, and Kathy Tonnessen

THE JACKSON LAKE SPRING SNAIL (*Pyrgulopsis robusta*) is presently known from only a single small stream near the boundary between Grand Teton and Yellowstone national parks (Wyoming). This snail is similar to other spring snails in the genus *Pyrgulopsis*, which are scattered in a few isolated populations across the Snake River and Columbia River watersheds. However, the Jackson Lake spring snail is a distinct population both geographically and morphologically. Its historical range included springs in the upper Snake River watershed above Jackson Hole, Wyoming. One of the last documented collection sites before 1975 was Elk Island in Jackson Lake.



Survey results show that the range of the endemic Jackson Lake spring snail (JLSS) is restricted to a small portion of its historical range. Within the present range, competition from the invasive New Zealand mudsnail (NZMS) threatens to reduce the Jackson Lake spring snail population.

Historically, the main pressure on the survival of this endemic snail was the damming of Jackson Lake and associated habitat modifications. Within its present range, however, the recent arrival of the invasive New Zealand mudsnail (*Potamopyrgus antipodarum*) might pose a new threat to the continued existence of the Jackson Lake spring snail. The current range of the endemic spring snail is restricted to a small portion of the historical range where it now competes with the nonnative mudsnail. In 2005, researchers from Grand Teton National Park, the University of Wyoming, and Washington State University explored the historical range of the Jackson Lake spring snail but found no refuge populations. These investigators will continue to search for the Jackson Lake spring snail in unexplored pockets of Jackson Lake and nearby thermally influenced springs.


The endemic Jackson Lake spring snail (*Pyrgulopsis robusta*; at top in the photo pairs) and the invasive New Zealand mudsnail (*Potamopyrgus antipodarum*; at bottom) can be difficult to distinguish in the field; however, the Jackson Lake spring snail is wider for its length.

Aquatic nuisance species have become a major concern for preserving the integrity of natural resources in many areas of conservation significance, including Grand Teton and Yellowstone national parks. The New Zealand mudsnail, a worldwide freshwater invader, has infested the habitat of a number of endemic spring snails listed as threatened or endangered in the intermountain West. The distribution of the New Zealand mudsnail is widespread and completely overlaps the remaining narrow range of the Jackson Lake spring snail. The spring snail is now rare in one of its last strongholds—Grand Teton National Park. Study results in 2006 by Bob Hall from the University of Wyoming and others show that the mudsnail population exists there at extremely high densities (>500,000 snails/m^2). The superior competitive ability of the mudsnail is threatening coexistence. In field experiments, New Zealand mudsnails grow faster than Jackson Lake spring snails under all conditions. Moreover, interactions with the spring snail have

Though investigators will continue searching for refuge populations, as of 2006 the Jackson Lake spring snail was known from one small tributary that runs between Grand Teton and Yellowstone national parks in Wyoming.

positive effects on mudsnail growth, while Jackson Lake spring snail growth is reduced in the presence of the New Zealand mudsnail.

Although the presence of the mudsnail slows the growth of the spring snail, strong evidence for competitive displacement of the Jackson Lake spring snail is not yet apparent and could take years to manifest. Investigators have monitored yearly variation in populations of the two species from 2001 through 2005 at five sites where both species are present. Samples collected in summer 2007 will help determine whether spring snail densities are indeed responding in a predictable manner to changing abundance in the mudsnails. Only continued monitoring will reveal how this native population will respond to a competitive invasive species.

The value of this research extends beyond the boundaries of Grand Teton and Yellowstone national parks and involves an array of federal, state, and private land managers who are striving to protect the valuable fisheries, water quality, and aquatic ecosystems of the Rocky Mountains. Basic research on the interactions between the introduced and native snail species was made possible through a collaboration of several partners with the Rocky Mountains Cooperative Ecosystem Studies Unit (CESU). This research, funded by the Greater Yellowstone Coordinating Committee, the Natural Resource Preservation Program, and the National Science Foundation, will enable managers in the Greater Yellowstone Ecosystem to understand the ecology of these competing snail species, devise management strategies to control the spread of the New Zealand mudsnail, and preserve remnant populations of the native spring snail. ■

leslie_riley@wsu.edu
Research Associate, School of Biological Sciences, Washington State University, Pullman

dybdahl@wsu.edu
Assistant Professor, School of Biological Sciences, Washington State University, Pullman

susan_o'ney@nps.gov
Resource Management Biologist, Grand Teton National Park, Wyoming

kathy_tonnessen@nps.gov
Research Coordinator, Rocky Mountains CESU, Missoula, Montana

Strategies for saving hemlocks in the imperiled forests of three West Virginia national parks

By John Perez

ONE OF THE MOST DIFFICULT ISSUES A LAND manager may face is the imminent loss of a species. But that is exactly what biologists expect to happen in the next 5 to 10 years now that the highly destructive hemlock woolly adelgid (*Adelges tsugae*) has infested the hemlock (*Tsuga canadensis*) forest of the three national park areas in southern West Virginia: New River Gorge National River, Gauley River National Recreation Area, and Bluestone National Scenic River. Hemlocks within the three parks form almost pure stands along many high-gradient stream corridors, and are frequently found as codominant canopy trees on 10,190 acres (4,126 ha). The hemlock is a keystone species within the Gauley River National Recreation Area, comprising 35% of the forest canopy, including outstanding examples of old-growth forest approaching 350 years in age.

Resource managers expected the adelgid threat several years ago, and in 1999, staff at New River Gorge secured funding to establish thirty-six 400-square-meter (4,306 sq ft) long-term monitoring plots. These plots have furnished seven years of critical pre-infestation data on the hemlock ecosystem prior to the arrival of the first hemlock woolly adelgid in 2004. This important data set is now being used by researchers studying ecological changes to the hemlock forest of the eastern United States. In 2005, entomologists from the USDA Forest Service, Forest Health Protection, Morgantown, West Virginia, conducted field surveys and prepared a biological evaluation that included a range of options to combat the infestation. No overall solution for the hemlock woolly adelgid pest problem is available, and pesticide treatments are effective only on individual trees. Therefore, the prognosis for the survival of the eastern hemlock ecosystem is very grim.

The Tree IV stem injection system is used instead of soil injection where insecticide must be kept away from waterways, where it would harm aquatic organisms.

The Kioritz soil injector delivers insecticide around the roots of a hemlock tree threatened by hemlock woolly adelgid.

Hemlock woolly adelgid populations are known to increase rapidly, with tree mortality occurring within 3 to 10 years of initial infestation. Therefore, park managers made a decision to aggressively implement all the recommendations in the biological assessment, and were successful in obtaining a $58,000 grant from the Forest Service. Areas identified for treatment in 2006 included old-growth forests, rare species habitat, sensitive aquatic resources, and high visitor-use areas. A three-member West Virginia Civilian Conservation Corps crew treated more than 1,533 trees on 534 acres (216 ha). They soon discovered that the use of the Kioritz soil injector (see photo) was the most effective method of insecticide application. The crew was able to treat about two dozen trees in the same time it took to

No overall solution for the hemlock woolly adelgid pest problem is available, and pesticide treatments are effective only on individual trees. Therefore, the prognosis for the survival of the eastern hemlock ecosystem is very grim.

complete a single stem injection. However, stem injections are the only authorized method of application in such areas as streambanks or wetlands, where insecticides have the potential to impact aquatic organisms. In addition, stem injections were used on trees located along cliff tops and in boulder fields, where soil injection was not possible. The Tree IV stem injection system (see photo) delivers insecticide directly into the sapwood (xylem tissue) but is less effective than the soil injections, which are viable for three or more years.

Without intervention, impacts to the hemlock ecosystem would certainly rival the loss of the American chestnut of the early 20th century. As the hemlocks disappear from the ecosystem, they will likely be replaced by early successional hardwood species. In Virginia, 90% of the hemlocks in Shenandoah National Park and along the Blue Ridge Parkway are already gone (see photo). Chemical insecticide treatments, though effective, are conducted on an individual tree basis, which is both labor-intensive and costly. Thus treatments are limited to those areas with outstanding biological resources or other high-value sites. The use of biological controls offers the best hope for long-range survival of hemlocks on a landscape scale. In 2006 the park released two species of predatory beetles (*Sasajiscymnus tsugae* and *Laricobius nigrinus*) in remote areas of old-growth forest.

We hope these efforts will have some effect in suppressing the infestation. In addition to aggressively treating as many hemlocks as possible, park staff will continue to inventory the 36 long-term monitoring plots and document changes in the hemlock forest. Though the future of the hemlocks does not look promising, park staffs will continue to examine the long-term monitoring plots for some indication that this outstanding element of our Appalachian ecosystem will not be lost. ■

john_perez@nps.gov
Biologist, New River Gorge National River, West Virginia

Before hemlock woolly adelgid infestation, this was a fine hemlock stand at Shenandoah National Park.

Merging ozone, plant leaves, science, and outreach

*By Colleen Flanagan, Robert Kohut, Ellen Porter, and Jennifer Stingelin Keefer**

BLEND FIVE NATIONAL PARKS, VEGETATION MAPS, experts in plant pathology, poor air quality, and ozone-sensitive vegetation such as common milkweed, tulip poplar, and cut-leaf coneflower. Garnish with hand lenses, tree climbers, scientists, volunteers, and a Research Learning Center. Sweeten with a dollop of trial and error and the result is the summer 2006 multi-park pilot assessment of foliar ozone injury.

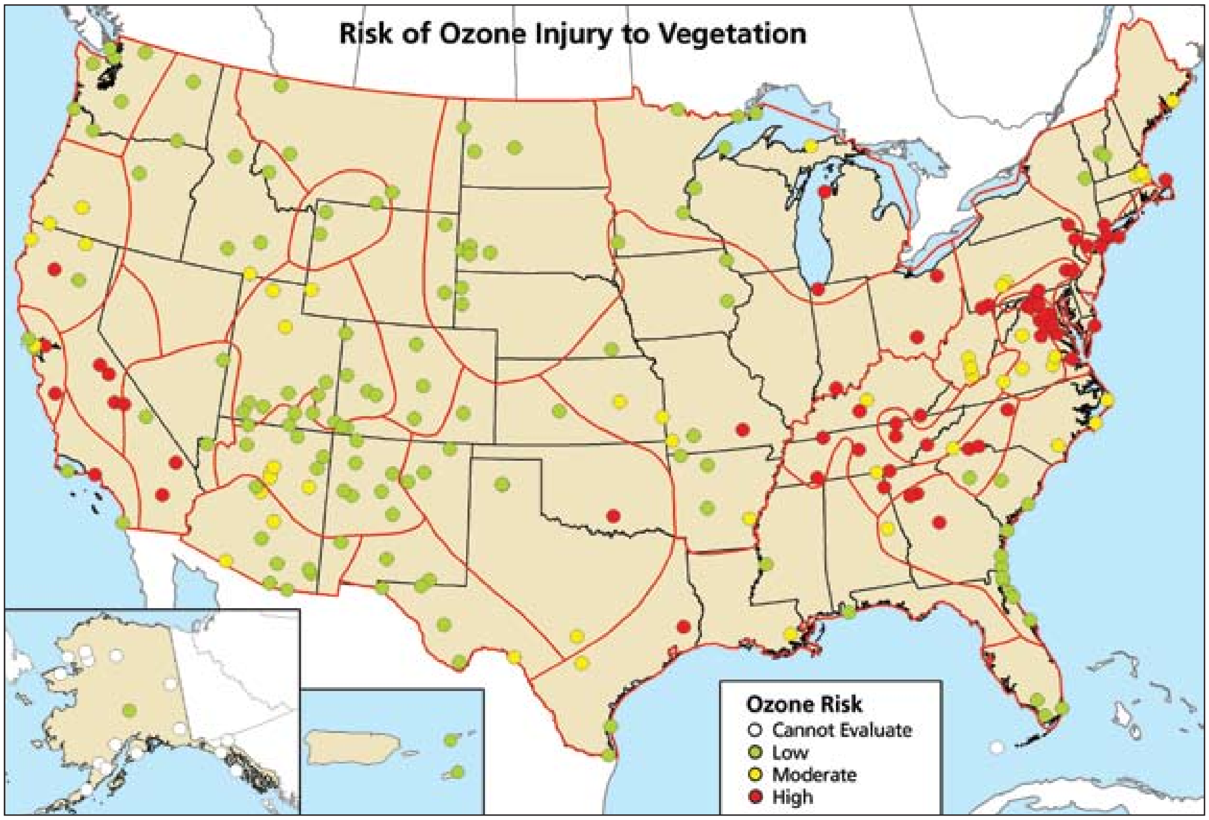
National parks that participated in the study were Allegheny Portage Railroad National Historic Site (Pennsylvania), Cowpens National Battlefield (South Carolina), Cumberland Gap National Historical Park (Kentucky), Mammoth Cave National Park (Kentucky), and Rocky Mountain National Park (Colorado). The objectives of the field program were to determine how well the *Handbook for Assessment of Foliar Injury on Vegetation in the National Parks*, developed by Dr. Robert Kohut of the Boyce Thompson Institute at Cornell University and the NPS Air Resources Division, served park staffs as they selected plant species to monitor, established field plots, and performed assessments of foliar ozone injury.

The handbook was extensively tested in each of the five parks from June to August 2006, and program participants gained insight into the changes and additions that will increase its utility. Each of the parks established an ozone injury assessment program, collected one year of data, and documented the presence of foliar ozone injury. Though overall it was a very effective resource, the handbook at times required the users to adapt the protocols to their specific park conditions. The field trials demonstrated problems associated with assessing leaves on trees that reach heights of more than 100 feet (31 m) (Mammoth Cave), the lack of plots with enough plants to meet handbook criteria (Allegheny Portage), and variation in the appearance of foliar ozone injury (Rocky Mountain). These and other issues illustrate the difficulty in developing a scientific "recipe book" applicable to all national parks in the 32 Inventory and Monitoring (I&M) networks, and confirm the need to employ sound scientific practices when a protocol is modified to meet specific field conditions.

Ozone, produced by photochemical reactions in the atmosphere involving emissions from combustion of fuels and other sources, can travel long distances, and occurs in high concentrations even in remote, rural areas—like national parks. It is especially highly concentrated in the eastern United States and in California, but ozone is also increasing in western states. In addition to harming human health, ozone harms plants. Ozone bioindicators, plant species that display distinctive visible leaf injury resulting from ozone exposure, act as sensitive warning systems of potential impacts of ozone on plant communities. Most national park units contain one or more bioindicator species. Lists, by park, of bioindicator species are available from NPSpecies, an NPS database of national park biodiversity.

A symptom of ozone injury—stipple—as found on common milkweed (*Asclepias syriaca*) at Allegheny Portage Railroad National Historic Site. This bioindicator was also used at Cumberland Gap National Historical Park and Mammoth Cave National Park during the 2006 surveys.

Ozone can produce both visible foliar injury (e.g., stipple and chlorosis; see photo) and growth effects (e.g., premature leaf loss and reduced photosynthesis) in plants. Though ozone does not kill plants, it stresses and weakens them over time. Ozone enters plants through leaf openings called stomata and oxidizes plant tissue, causing changes in biochemical and physiological processes. These changes result in less carbon for growth and reproduction, and less carbon to allocate to storage in the roots for overwintering. Seed production and germination potential may also be reduced, with possible population-level effects. Over several years, these effects have a cumulative impact on the plant, reducing its vigor and making it more susceptible to insects and pathogens.



Risk of ozone injury to vegetation in the 270 national parks (dots) located in the 32 I&M networks (red lines).

Foliar ozone injury was found on bioindicator plants in each of the five parks that participated in the pilot assessment. Previously, ozone injury had been documented in other national parks, including Acadia (Maine), Great Smoky Mountains (North Carolina/ Tennessee), Shenandoah (Virginia), Sequoia/Kings Canyon (California), and Yosemite (California). A risk assessment completed by Dr. Kohut and the Air Resources Division (2003–2005) concluded that about 28% of 270 parks in the I&M networks were at high risk of ozone injury. Most of the parks at risk are clustered in the mid-South, mid-Atlantic, and southern California regions (see map).

Measuring ozone bioindicator health provides information about the condition of park vegetation that management can use to influence regional air pollution control programs. Ozone injury monitoring data can also be used to inform and educate the public about the consequences of elevated ozone levels. The Appalachian Highlands Science Learning Center, for example, has incorporated ozone injury monitoring into middle school educational programs (http://www.nps.gov/archive/grsm/pksite/index.htm). Budgetary and time constraints will affect whether ozone injury assessments will continue at the five pilot parks through the 2007 season and beyond. However, a long-term monitoring program can establish relationships between air quality and foliar injury, and can identify trends in foliar injury.

Based on observations and feedback from the five pilot parks, the revised handbook will be completed by the end of summer 2007 and posted at http://www2.nature.nps.gov/air/Permits/ARIS/networks/index.cfm. Staffs at national parks that identify air quality and ozone as a concern will be able to download and implement the assessment protocols it provides. ■

Colleen Flanagan
Former Lead Biological Science Technician, Continental Divide Research Learning Center, Rocky Mountain National Park, Colorado

rjk9@cornell.edu
Plant Pathologist, Boyce Thompson Institute (retired), Cornell University, Ithaca, New York

ellen_porter@nps.gov
Biologist, NPS Air Resources Division, Lakewood, Colorado

jls227@psu.edu
Botanist/Research Associate, Pennsylvania State University, University Park

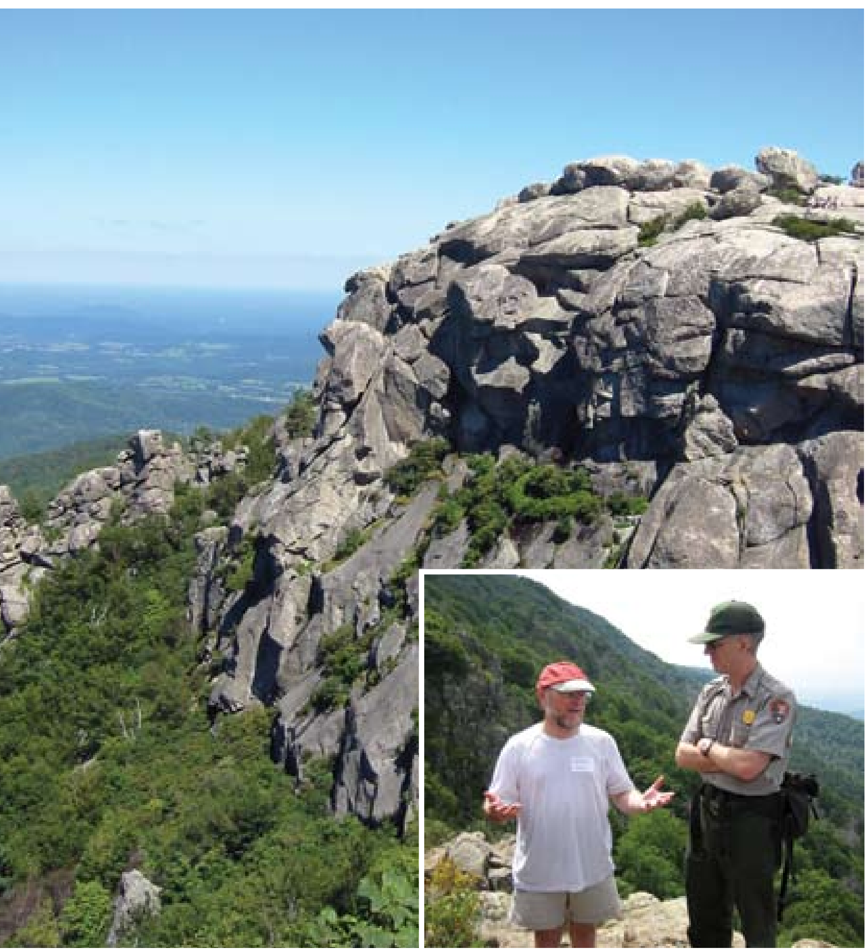
*Additional reporting by Kathy Penrod and Bobby Carson, National Park Service.

Finding balance: Protecting the visitor experience and rock outcrop natural resources at Shenandoah National Park

By Wendy Cass

ROCK CLIMBERS AND HIKERS FLOCK TO THE coarse granite and rugged topography of Old Rag Mountain at Shenandoah National Park, filling the 200-vehicle parking lot to capacity on fall weekends. Sensitive natural resources also concentrate on Old Rag, including state-listed rare plant species, two globally rare plant communities, and nesting sites for the peregrine falcon (*Falco peregrinus*). Trampling damage to rare plant species and communities is a long-standing problem on the mountain's summit.

Finding ways to protect rare natural resources that occur within popular hiking and rock climbing areas without restricting the visitor experience is an ongoing challenge at the park, located on the crest of the Blue Ridge Mountains of Virginia, and seeing 1.1 million visitors annually. Attempts to redirect visitors to less sensitive areas have met with mixed success and have been plagued by law enforcement difficulties. Closing areas to visitors might be the most desirable solution to protect rare resources. However, this option is incompatible with recreation, unenforceable, and likely to shift impacts to other sensitive sites.



To protect fragile natural resources at certain sites from damage by visitor activities, the Rock Outcrop Management Project has engaged the public. Shenandoah National Park Superintendent Chas Cartwright listens to a visitor's concerns during an on-site field trip to discuss rock outcrop management issues.

The Shenandoah Rock Outcrop Management Project (ROMP) was born of the realization that park staff needed to take a comprehensive approach to managing the combination of visitor use and resource protection of these sensitive areas. The three-year (2005–2007) project, funded by the Natural Resource Preservation Program, is an ongoing example of successful collaboration among National Park Service managers, state and university natural resource experts, and user groups. This large, interdisciplinary project is combining aspects of mapping, resource inventory (zoology, botany, and geology), recreational use and impact assessments, and public education and outreach. It will conclude with the development of a comprehensive rock outcrop management plan for the park.

The majority of ROMP funding has been used to complete natural resource inventories and to assess visitor use and impacts. The resource inventories found that 96% of the 50 ROMP sites had significant natural resources. Botanical findings included nine globally rare plant communities, two of which are endemic to the national park, six previously undescribed lichen species, and 19 state-listed rare plant species. Zoological discoveries included the federally listed endangered Shenandoah salamander (*Plethodon shenandoah*), the state-listed threatened peregrine falcon, the state-listed rare small-footed bat (*Myotis lebii*), and seven state-listed rare invertebrate species. Forty percent of these sites exhibited moderate to severe human impacts in the form of unofficial trails, campsites, rock graffiti, trash, and soil and vegetation damage.

The establishment of frequent, open communication with park user groups is a central component of the Rock Outcrop Management Project. Close attention to this need has built good rapport with user groups, and helped the project avoid the pitfalls of mistrust and negativity that can taint interactions between the public and government.

Close attention to [frequent, open communication] has built good rapport with user groups, and helped the project avoid the pitfalls of mistrust and negativity that can taint interactions between the public and government.

One key strategy was initiating interaction with the public very early in the project planning process. Within the first six months, project coordinator Steve Bair was sending overview information to an e-mail list of organizations and individuals likely to be interested in the project. Shortly thereafter the park held widely advertised public workshops to explain the project objectives, gather people's concerns and suggestions, and answer questions. The feelings of mistrust were palpable at these first meetings. However, interactions began to warm after the workshop summary notes were distributed, and park staff made extensive efforts to follow up on the questions, concerns, and suggestions voiced during the workshop.

On a ROMP-sponsored field trip attended by 35 people, park staff and the public discussed resource protection and visitor concerns. For example, trails associated with climbing activity ran through several rare plant populations. Once on-site, however, all parties agreed that the closure of one climbing route, combined with minor trail relocations and educational signs, was acceptable to all. In another instance, the majority agreed that the mountain's secondary summit, currently accessed by an unofficial trail, could be closed to visitors to protect sensitive vegetation, with only minor effects on the experience of climbers and hikers. The field trip was extremely helpful in identifying possible solutions.

Maintaining constant open communication has not been easy, and interactions have not always been amiable. However, the collaborative approach used in this project has allowed concerns to be voiced and addressed before they might become larger sources of frustration and misunderstanding. After many months the project has finally yielded a mutually trusting relationship between the park and stakeholders. The Shenandoah Rock Outcrop Management Project will conclude in 2007 with the completion of a comprehensive environmental assessment and management plan for rock outcrop areas within the park. These plans will not hold any surprises for stakeholders because they have been involved throughout the development process and understand the logic behind the decisions. ■

wendy_cass@nps.gov
Botanist, Shenandoah National Park, Virginia

Old Rag Summit tempts climbers to ascend, but the special ecosystem associated with these rocks is threatened by the climbers' activity. A three-year management project has resulted in greater protection of rare plants and animals living on the rock outcrop while preserving use of many popular climbing routes.

Visitor impact mapping monitors the condition and management of Oregon Caves

By Elizabeth Hale

MANAGING VISITOR IMPACTS IS A FREQUENTLY considered factor along heavily traveled corridors on park lands, whether above or below the surface. However, more so than on the surface, visitor impacts in caves tend to be cumulative and difficult or impossible to reverse. A cave is a low-energy environment, where the slow dripping of water builds flowstone and draperies out of calcite, and darkness and limited food sources cause organisms to adapt in ways not observed anywhere else. It is an environment where thousands of high-energy human visits annually can have a profound impact on its aesthetic and ecological integrity.

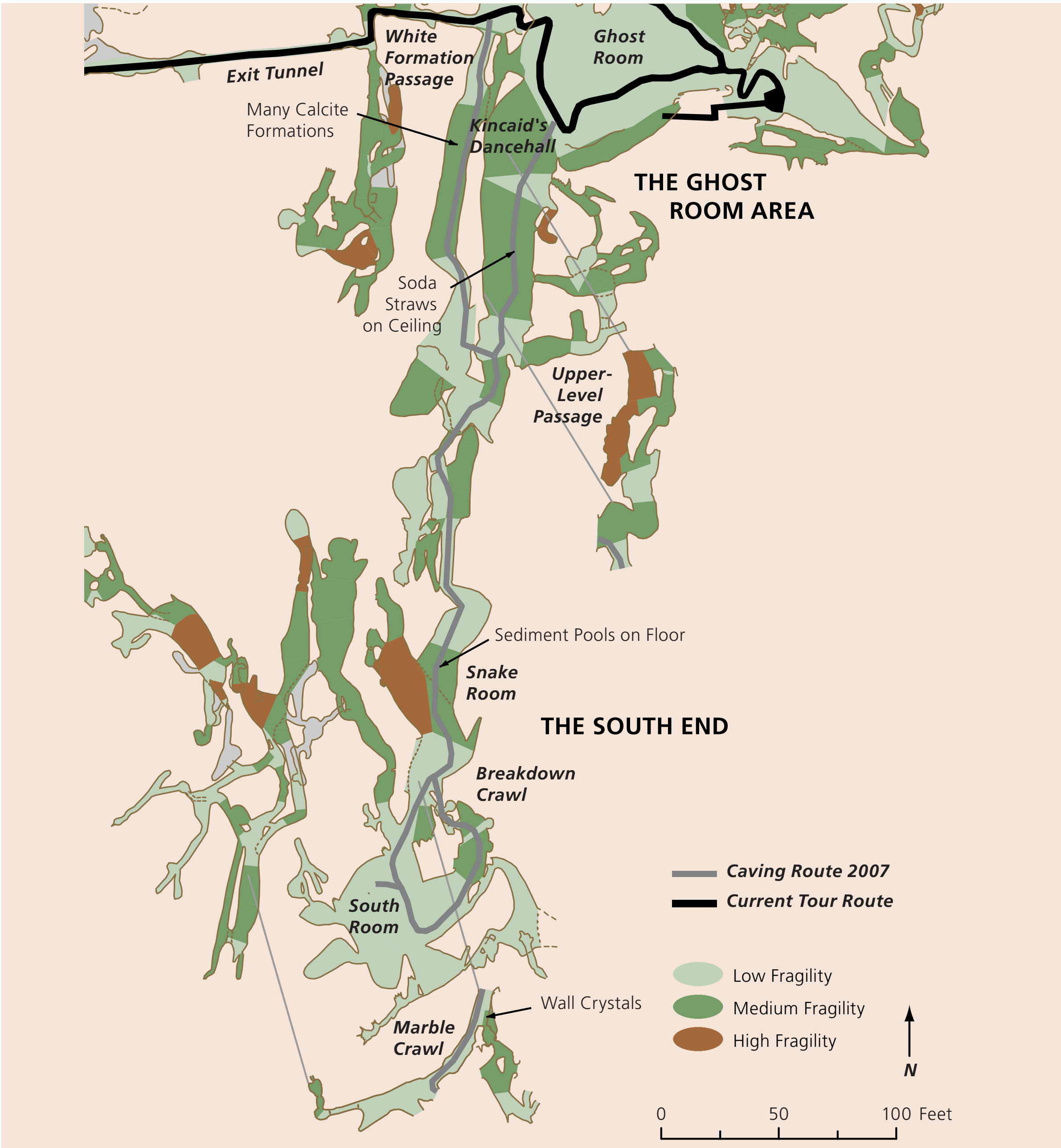
In 2006 a project to comprehensively map visitor impacts with Geographic Information Systems (GIS) at Oregon Caves National Monument gave resource management staff the opportunity to develop new methods for understanding the severity, extent, and nature of impacts on a cave system. Visitor impact mapping (VIM), a concept credited to caver Hans Bodenhamer, is a technique for monitoring a cave's condition with maps of impacted surfaces and damaged or vulnerable features. Over time, "impact maps" reveal how well cave management practices have protected the cave and can guide decisions about cave use. An intensive VIM effort at Oregon Caves, incorporating GIS layers, inventories, assessments, and geographically linked digital photos, is helping park managers find the balance of providing for recreation, research, and education while protecting cave resources.

Oregon Caves has a 0.6-mile (1 km) paved tour route and is visited by about 48,000 people annually. Many visitor impacts in the cave are readily visible along this route: stalactites broken off for souvenirs, flowstone surfaces scratched and scarred from path construction and the resulting rubble, and calcite formations that are darkened or polished from touching. Less obvious are the trace amounts of lint, skin, and hair that each person leaves behind. Organic, human-caused debris, as well as algae growth around tour-path lighting, can serve as food sources for nonnative species. Along the new "off-trail" caving tour, which opened in summer 2007, and in other off-trail passages of the cave, deposits of sediments and animal bones and fossils are vulnerable to disturbance.

Foot traffic increases the bulk density of sediments on the cave floor. This may affect microbial activity and biodiversity, water infiltration rates, and amount of runoff. However, quantifying dramatic visual differences is not as easy as it looks.

The focus of VIM project work was to inventory and quantify visitor impacts in the cave and to establish data sets and methods for monitoring. Prior to this project, related efforts to assess and monitor the cave's condition included establishing fixed-point photomonitoring stations and classifying cave passages according to the hazards they present and their vulnerability to impairment. From summer 2006 through winter 2006–2007, resource management staff revisited the photomonitoring stations to make a new photo set, mapped algae growth around tour lights, and conducted inventory along heavily used passages for the presence and severity of 29 types of impacts. Staff also surveyed and photographed more than 140 bone sites and created a photo inventory of more than 80 features of concern or value. The result of the integration of this fieldwork with preexisting data sets is an expandable geodatabase that contains mapping and monitoring data related to understanding and mitigating visitor impacts.

Park managers will use project data to closely monitor the impact of off-trail caving tours, which will use a part of the cave that has not previously been toured by the public. Baseline data sets, including photos tied to specific locations and dates, the point locations of bone deposits, and an inventory of visible impacts and their severity along the caving route, will be compared with future route conditions to evaluate the impact of off-trail tours. In the meantime the existing data suggest that the impacts most likely to increase from caving tours are polishing of rocky surfaces used for footholds and handholds, sediment compaction on floor surfaces, and hair and lint accumulation. This has led to the recommendation that visitors wear bandanas to secure their hair, and the placement of flags and markers to designate specific paths through the area.



Data collected from the Visitor Impact Mapping project, like this criteria-based fragility assessment of Oregon Caves' passages, help with resource protection planning for the new "off-trail" caving tour. This map shows the vulnerability of Oregon Caves' passages to visitor impact and points out specific fragile features along the caving route, which does not go through any high-fragility passage.

Additionally, hazard-fragility classifications and the knowledge of bone-site locations along the route will pinpoint where guides need to emphasize safe caving techniques to avoid hazards and protect resources.

As part of the VIM project, a sediment compaction assessment and a vandalism inventory (where broken formations are tagged with UV-fluorescent marks to identify if and where new breakage occurs) will be completed in late 2007. Other efforts, such as monitoring total ionic concentrations in trailside pools and fixed-point photomonitoring, are ongoing.

Visitor impact mapping at Oregon Caves strives to protect the cave's nonrenewable resources with a high level of detail and care. A cave, because of its fragile nature, is best treated as a still pool—one where we want to make as few ripples as possible. ■

elizabeth_hale@nps.gov
Physical Science Technician, Oregon Caves National Monument, Oregon

EarthCaches at Acadia National Park: Virtual treasure hunts educating visitors on the richness of park resources

By Ginny Reams and Stuart West

Unlike Acadia's virtual EarthCaches, traditional caches typically include a container filled with a logbook and other trinkets and "treasures" that can litter the landscape. Placement of traditional caches may also require participants to leave established trails, which damages vegetation and can harm other natural or cultural resources.

STAFF AT ACADIA NATIONAL Park (Maine) are turning the growing interest in geocaching, a modern-day treasure-hunting activity prohibited in most National Park System units, into a park-sponsored program that educates visitors on the geologic riches awaiting them within park boundaries. In summer 2006, park staff, led by Park Ranger Stuart West and volunteer Mollie Behn, developed a pilot NPS-hosted educational program that emphasizes the unique natural features of the park through virtual "EarthCaches," educational messages that impart knowledge without impacting the environment.

Geocaching is an activity in which participants search for hidden caches using Global Positioning System (GPS) units, and it has become increasingly popular since its creation in 2000. More than 340,000 caches were active worldwide as of December 2006 (Groundspeak 2006). After all, who can resist a treasure hunt? Whose heart doesn't beat a little faster when faced with the adventure and thrill of following a trail littered with obscure clues toward a final reward?

Leaving items behind, however, is one of the problems associated with the physical creation of a traditional geocache. In traditional geocaching, individuals and organizations set up caches and share their location coordinates via an Internet Web site. GPS users then use those coordinates to search for the cache. Caches can take many forms, but all contain a logbook for recording comments. Traditional caches can also contain items purposely left behind by previous visitors (see photo). These items vary from small, inexpensive knickknacks to maps, books, games, or even loose change. Anyone who takes an item (or "treasure") is expected to leave something in its place.

Though rugged, unspoiled natural areas may seem to be desirable spots for hiding—and seeking out—geocaches, their presence in U.S. national parks can be troublesome. Unintentional damage caused by the inappropriate placement of a cache or by participants who develop social trails when they leave established trails to look for a cache can result in serious impacts on a park's natural, historical, and cultural resources. Because federal regulations pertaining to national parks prohibit abandonment of property, disturbance or damage of natural features, and, in some areas, off-trail hiking, most units of the National Park System, including Acadia, do not permit geocaching. In some sites, however, such as national recreation areas, geocaching may be permitted. This disparate treatment of geocaching creates a problem for the geocaching community and a challenge for National Park Service employees who are asked to explain the reasons behind it.

Despite the prohibition against geocaching in Acadia, unauthorized geocaches are often located within national park boundaries. Since 2000, park rangers have found and removed at least 17 physical geocaches from Acadia National Park lands. An additional 21 geocaches are now located on Mount Desert Island outside park boundaries.

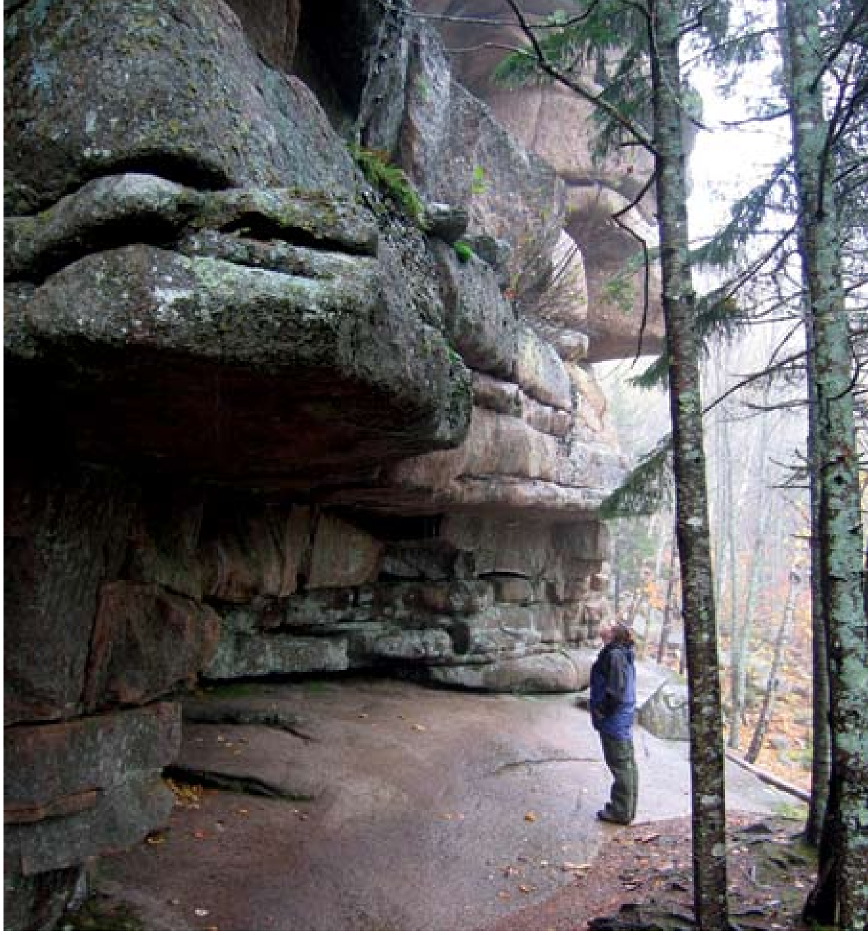
With the increasing popularity of geocaching and related GPS-driven activities as well-established, international pastimes, Acadia National Park staff began looking for a means to protect park resources while providing the geocaching community with an exciting way to enjoy those resources. In consultation with Marcia Keener of the NPS Office of Policy, Geological Society of America (GSA) staff, and local geocachers, Acadia National Park staff settled on the creation of a more environmentally sensitive caching activity based on the GSA's EarthCache concept.

Unlike geocaches, EarthCaches are a type of virtual (nonphysical) cache that teach something about the site—how it was formed geologically, why it is important scientifically, what it can tell us about our planet—without impacting the environment (see photo). There is no physical cache full of objects. With EarthCaches the knowledge gained is the treasure. To ensure appropriate educational content, EarthCaches are judged for suitability by the EarthCache team, which is part of the Geological Society of America. The concept of EarthCaches was developed by Gary Lewis of the

Geological Society of America and Judy Geniac and Bob Higgins of the National Park Service.

The Acadia National Park EarthCache Program includes a series of park-developed "offset" caches—caches that take the seeker to more than one location along the trail toward the treasure. After downloading background information and starting coordinates from the park Web site (http://www.nps.gov/acad/earthcache.htm), participants begin the treasure hunt. At each location, caches offer educational messages about the park's geologic resources and clues to determine location coordinates to subsequent caches. Instead of physical containers, these caches are small, laminated posters hidden from public view. The final cache is a letterbox cache, located inside a park facility, that includes a logbook and a stamp for marking the personal logbook of participants. The lack of traditional physical caches and the park's selection of areas used in the program, including durable surfaces for cache locations, prevent resource damage and enhance visitor safety. The experience is designed to be challenging and informative and to help foster appreciation, support, and protection of Acadia National Park.

The EarthCache Program is being tested by park staff and experienced geocachers as part of its pilot phase and will be available to the public by spring 2007. Because it was developed cooperatively, Acadia's EarthCache Program can meet the needs of a number of different audiences. It appeals to the geocaching community by providing a fun, innovative, and educational way to explore the outdoors using current technology. It allows park staff to meet its resource management, resource and visitor protection, and interpretation objectives. It also offers an alternative to traditional geocache activities across the National Park System. By offering participants a new adventure in the national parks, EarthCache programs like Acadia's provide opportunities for visitors to build vital connections with extraordinary resources. Not a bad outcome for a virtual treasure hunt. ■



Each stop in Acadia's EarthCache Program highlights some of the park's significant geologic resources. (Top) Volunteer Mollie Behn studies a sea cave that today sits well above sea level. (Bottom) A participant studies a sea stack formed by the ocean's erosive power.

Reference

Groundspeak. 2006. Geocaching—The official global GPS cache site. Frequently asked questions page. Groundspeak, Seattle, WA. Available at http://www.geocaching.com/faq (accessed 20 December 2006).

virginia_reams@nps.gov
Writer-Editor, Acadia National Park, Maine

stuart_west@nps.gov
Branch Chief—Remote Areas, Acadia National Park, Maine